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Mitigation and Discrimination of Inrush Currents in Three Phase Power Transformer

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Abstract: ***The Electrical Power Transformer is the essential part in Power System and this Power Transformer is protected by the relay with main circuit breaker. In this Almost there is no possibility of external fault condition to it other than the internal faults like open circuit faults, winding short circuit faults. The Inrush current occurs in the transformer during switching on of a transformer and it may be rising up to 10 times the normal load current of an electrical power transformer during switching on operation. Then it is considered normal operation. Electrical Transformer is often tripped during inrush current flows in the system causing many problem in operation of transformer and customer disturbance. The technique Point on wave switching method is used to reduce the inrush currents of a transformer initially connected to the supply. In this method the energising of three phases are controlled by the residual flux which remains in the power transformer. It is necessity to discriminate the inrush currents and fault currents. For this a different method of discrimination of inrush and fault current considering current waveforms with the help of Fuzzy logic controller technique is considered.***
Keywords: Magnetization current, Point on Wave, Discrimination, Energisation, Harmonic.

I. INTRODUCTION

Transformer is an important, essential and costlier element in power system. So, the protection of transformer have the same importance. Protection of Three Phase Electrical Power Transformer, a digital differential protection is applied in which terminal currents are used. In transformers, abnormal conditions like faults are divided into two categories:-1) Internal 2) External. The phenomenon of internal fault which is originating a profound effect internally on lifetime of an Electrical transformer. During the external faults, short circuit will forces become very much threatening for hidden defects and aged insulation and often causes inter turn shorting. The older aging of insulation materials due to its temperature, specifically at points of a local overheating and is accelerated in the occurring of oxygen and moisture. The Hidden defect is also responsible for insulation physical strength. Usually Internal fault occurs at the high level voltage side in signal phase, and is initially number of turns are small.

In practical power system, during switched on of transformer, it produces high currents in the power transformer that can causes to trip circuit breaker. Some other major circumstance were the same position can arise when the power transformer is on no load condition and secondary side is open. A high magnetization current produced by the transformer is the reason for the above mentioned issue. The current may be reaching a level exceeding its full load of current. This type of high currents are known as the Inrush Currents. Magnetization Current are in the form of high current that occurs when transformer is energised and high transient current which is occurs due to part cycle saturation of the magnetic core of the transformer. In a power transformers, the inrush current magnitude is initially 6 to 10 times higher than the rated load current. It's gradually decreases by the effect of damping oscillation due to magnetising resistance and winding of the transformer and also the system impedance it is connected to, until it becomes the normal load current value.

In practical power system, transformer inrush current are taken as a critical problem. Due to its high current it can cause effects like insulation failure, mechanical stress on the transformer windings, introduction of power quality issues, and can also affect the protection devices. From several years onwards researchers have analysed and worked the different ways to find and mitigate this inrush current. The various factors affects the magnitude of inrush current is:

1) The transformer core residual flux.
2) The transformer core non – linear magnetising characteristics.
3) The phase of the source voltage at the time of the transformer energising.
4) The short circuit power and impendence of the supplying source.

II. INRUSH CURRENTS

At the time of electrical devices turn on it draws high magnitude of input current is known as Inrush Current. It can appear for few seconds or cycles of the input waveform. When the power transformer runs in normally, the flux induces in the power transformer

core is quadrature with supply voltage. Inrush current produces in a power transformer due to the mismatch of residual flux to the instantaneous steady state flux value.

For explaining the effect of magnetization current in power transformers primary winding is connected to an ac voltage supply, the equation to be considered as

$$v = d\emptyset/dt \quad \text{equation (1)}$$

Where v and Ø are the voltage drop at the primary winding and the instantaneous flux of the transformer core and respectively.

From equation (1), we can understand that the voltage across the transformer primary is proportional to the rate of change of flux in the transformer core. The flux due to the nonlinear characteristics of the magnetising curve effects due to the saturation of core. The transformer flux waveform is to be considered as the integral to the voltage waveform. In continues operation of power transformer, with these waveforms are shifted 90˚. If the flux waveform is at its negative value of peak, the voltage is at zero. In this case of the flux will start from zero, but transformer does not energised.

From the Faraday's law of Electromagnetic Induction, the voltage induced across the winding is given by:

$$e = d\emptyset/dt \quad \text{equation (2)}$$

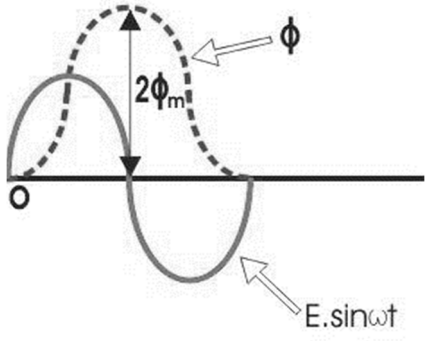

Figure 2: Voltage - Flux Graph

Where Ø is the core flux. Hence this flux is the integral of the voltage. If the power transformer is switching on at the instant of voltage is zero and also the flux is started from the same origin as that of the voltage. Therefore, the flux value at the end of the first cycle will be:

$$\emptyset' = \frac{E}{\omega}\int_0^{\pi} \omega sin\omega t.dt$$

$$= \emptyset \int_0^{\pi} sin\omega t d(\omega t)$$

$$= 2\emptyset m$$

III. MITIGATION TECHNIQUES OF INRUSH CURRENTS FOR POWER TRANSFORMER

Several transformer magnetization current mitigation methods are to be proposed over the years of its advantages and disadvantages. Not all of them, however, are easily implementable or economically feasible. In what follows, the salient aspects of several of these proposals, are reviewed. Given, however, point-on-wave switching, these techniques are reviewed in more detail.

A. Point on wave switching(POW) Technique

Point on wave controller is also called as Point on wave switching. This controller is used for switching of shunt reactor, power transformer, and transmission line and capacitance bank. This POW may lead to over voltage high frequency and inrush currents. Basically the POW synchronizes the random ON or OFF the breaker at pre determines point at given voltage waveform.

By using this technique to reduce the energisation of inrush currents in power transformer. In this technique the strategy will close all three phases of residual flux of an optimum point. This method will not require any independent pole breaker control, but need know about knowledge of residual flex in three phases and residual flux magnitude in two phases that are high and also flow the most regular residual flux pattern. These closings are selected as part of a magnetization inrush current mitigation for the 3-phase transformer that enables the usage of the 3-pole circuit breakers.

B. Pre fluxing Method

Reduction strategy of Inrush currents method, which sets of a 3-phase transformer residual flux to specific polarity and high magnitude, this method known as a Pre fluxing method and it energizes the 3-phase transformer at a fixed system voltage angle depend on its flux polarity.

Pre fluxing method sets a simple form of flux to a 3-phase transformer and this can be very flexible to set for any type of transformer. The energizing a pre fluxed transformer results were presented, which includes accounting for breaker divergence; it proves the efficient of reduction procedure when the magnetisation current levels below the transformers rating. Beyond this method the reduction strategy of pre fluxing magnetisation current present in the Pre fluxing device itself. By using this method the capacitance is charged to a user defined voltage and it is discharged into the 3-phase transformer during the device switch is closing. It is required for minimizing the magnetization currents in the transformer by set the residual flux of a pre fluxing device, but also to do effectively. The reduction strategy of Pre fluxing method is a 2 part process. 1st, the power transformer residual flux is fixing as nearer to its maximum achievable residual flux when the 3-phase power transformer is de-energized. The 2nd part of the process that controls the circuit breaker to energize the power transformer at an angle 210 for the residual flux is positive (or) 330 for the residual flux is negative. Those angles were chosen as a part of a magnetization inrush current reduction strategy for 3-phase transformers is enabling the use of a 3-pole CB.

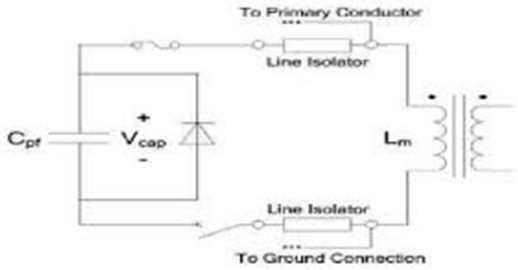

Figure 3: Pre fluxing method

The Pre fluxing method is shows in the above diagram and it consists of a fuse, a switch, a capacitor, and a diode. A charging circuit (not shown) establishes the starting voltage from side of the capacitor. This device is used during in the power system the 3-phase transformer is isolated and connected across winding of transformer. In the best possible, the high voltage winding is used because of the reduced magnetizing current on this winding.

IV. FUZZY LOGIC CONTROLLER

Fuzzy logic controller method is applied with the great positive result in different controlling application. Fuzzy logic controller was applied to consumer products almost all. Different types of examples to anti-braking system for vehicles, by the help of air-conditioner to controlling room temperature and traffic lights controlling, washing machines, large economic systems, etc.

A. Fuzzy Controller Construction:

1) Creating a membership values.
2) Rule table Specification.
3) Defuzzyfing the values.

V. MATLAB SIMULATION

In the MATLAB simulation first is model for inrush current in a power transformer, second model is by applying POW method, third model is by applying Pre fluxing method and final method is to discrimination of magnetization currents from internal fault currents in power transformer using fuzzy logic controller.

A. Mitigation Of Inrush Currents Simulink Model:

The Power Transformer rating is 300MVA, 11kV/400kV 50Hz, connected to a 11kv supply source. The 3-phase transformer used in this project for simulation has Y-Y connection of winding. When the transformer is energized and the flux of all 3-phases will increases and reaches till the maximum flux value and after that the maximum value of flux will be saturated and draw more current from source, which may be 5 to 10 time greater than rated current.

In this project, Mitigating of inrush currents uses two techniques, one is POW technique and another one is Pre Fluxing technique. In this Simulink model the 3-phase transformer contains core magnetization resistance 154ohm and magnetization inductance of core is 8.4mH. The Simulink model of mitigation inrush currents are shown in below

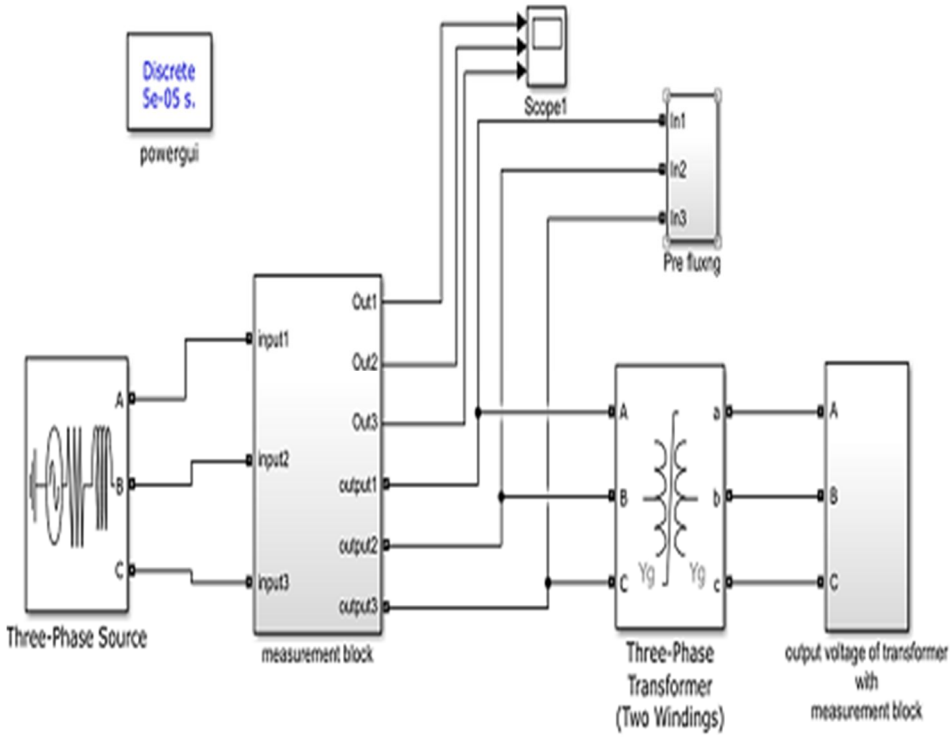

Figure 4: Mitigation of Inrush currents

B. Fuzzy Controller Simulink Model:

In the output block we have only one single output with six different parameters, Normal condition with the range from 1 to 0, Inrush current with the range from 2 to 1, LG type fault with the range from 3 to 2, LL type fault with the range from 4 to 3, LLG type fault with the range from 5 to 4 and LLLG type fault with the range from 6 to 5.

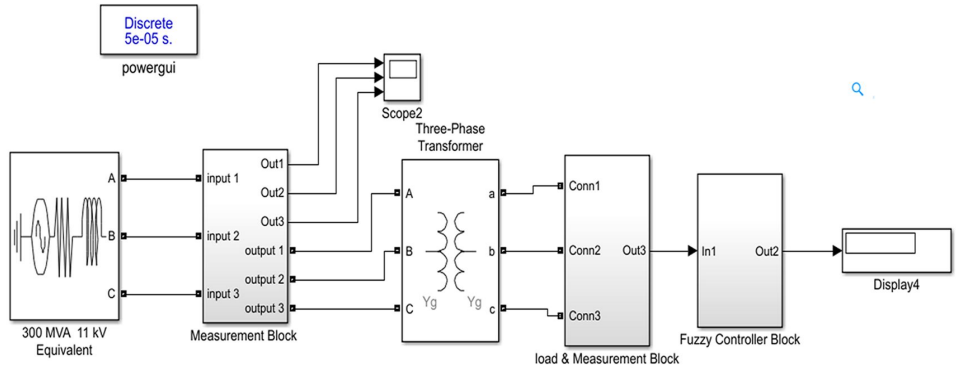

Figure 5: Discrimination of inrush currents using Fuzzy Controller

VI. SIMULATION RESULTS

Analysis of simulation we studied about the inrush currents and discriminate the Fault currents from Magnetization Inrush Currents in a Power transformer. In the analysis of inrush currents there I am using two methods. POW method and Pre fluxing method to mitigation of inrush currents in Power Transformer. For Discrimination of Magnetization inrush currents from fault currents in a Transformer by applying Fuzzy Controller technique to discriminate. For every technique there will be separated results as shown in below.

Magnetization Inrush Currents in Transformer Simulation Results:

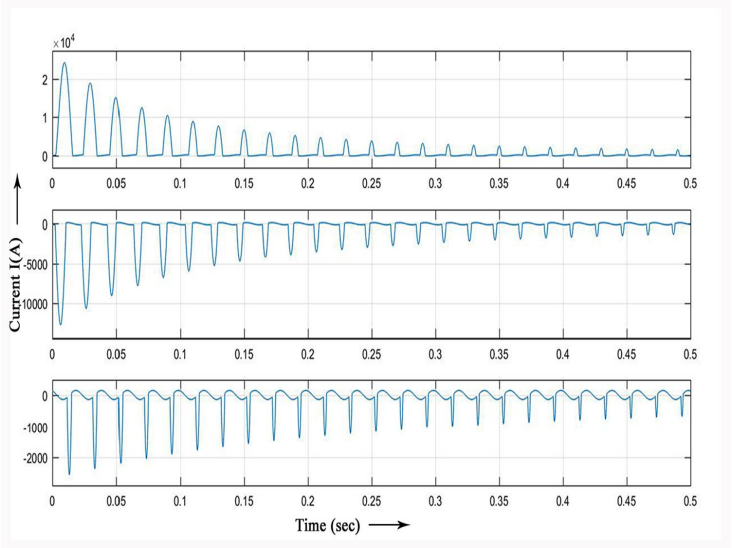

Figure 6: Inrush Current in Transformer

Mitigation of Magnetization Inrush Currents in Transformer Simulation Results:

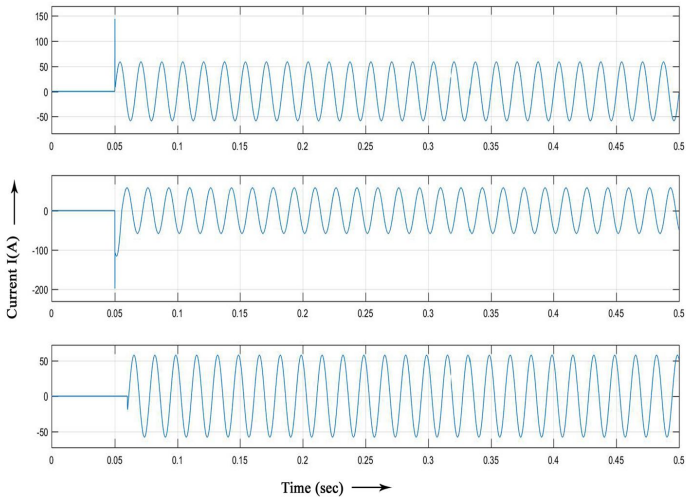

Figure 7: Mitigated Inrush Currents by Pre fluxing technique

A. Difference Between Point On Wave Method And Pre fluxing Method of Inrush Current Values:

TABLE I
Differentiation value of Inrush Current (in Ampere)

	Phase A	Phase B	Phase C
Inrush Current	20746 A	9283.56 A	9180.38 A
Mitigated Inrush Current By Using POW Technique	5341 A	2210 A	10065 A
Mitigated Inrush Current By Using Pre fluxing Technique	55.50 A	55.86 A	55.25 A

In Table shows the value of Magnetization inrush currents in a Power transformer having a ratings of 300MVA, 11KV/400KV is 20746 Ampere. By using mitigation technique we have to reduce it. So firstly I applied POW (Point on Wave) method due to which inrush current reduces to 5341 Ampere, after that I applied Pre fluxing technique which reduces the value of Magnetization inrush currents to value 55.50 Ampere which is very low as compared to starting inrush current.

B. Fuzzy Controller Output

1) If output between 0to1 that means there is Normal condition.
2) If output between 1to2 that means there is Inrush current condition.
3) If output between 2to3 that means there is LG Fault current.
4) If output between 3to4 that means there is LL Fault current.
5) If output between 4to5 that means there is LLG Fault current.
6) If output between 5to6 that means there is LLLG Fault current.

a) Fuzzy Controller Output: Here the fuzzy controller output, that can discriminate the currents like fault, inrush and normal currents as show in the below.

i. Normal Operation: The output of Controller is 0.51 that mean No Fault No Inrush currents

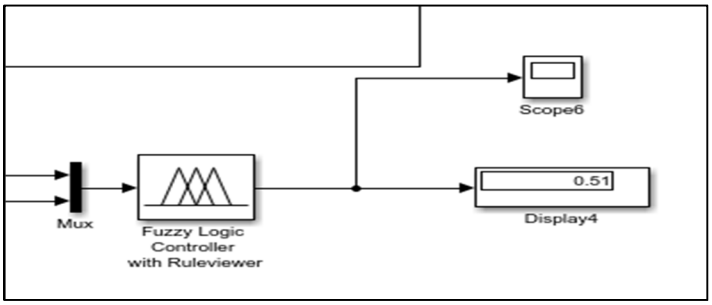

Figure 8: In Normal condition

ii. LL Fault: The output of Controller is 3.501 that means Fault is LL type

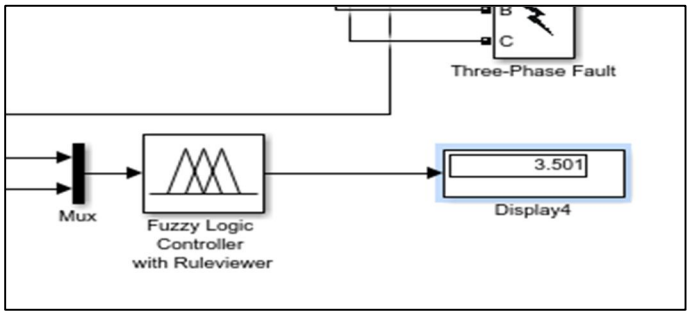

Figure 9: LL Fault

iii. LLLG Fault: The Output of Controller 5.499 that means Fault is LLLG type

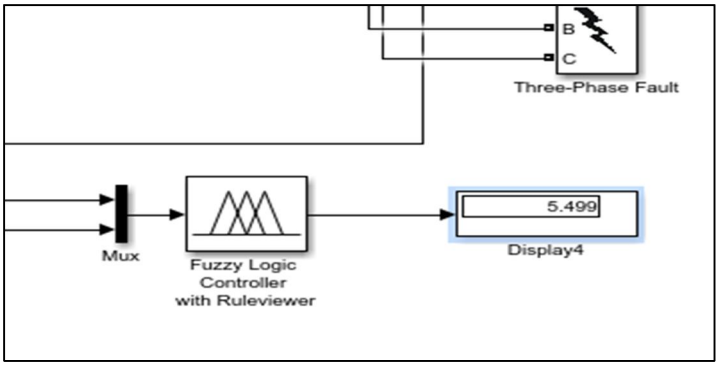

Figure 10: LLLG Fault

TABLE II
Discrimination Results Of Using Fuzzy Controller Technique

Fault type	Fuzzy controller output
Normal condition	0.51
Inrush Currents	1.5
LG	2.49
LL	3.5
LLG	4.5
LLLG	5.49

VII. CONCLUSION

The above results show that simulation of POW Method is to be reduction of magnetization current in a power transformer. Also show mitigated magnetization current using Pre fluxing device in power transformer quickly. After comparing the Point on Wave(POW) technique and Pre fluxing technique, it is found that the values of magnetization inrush currents in power transformer are mitigated, but Pre fluxing technique mitigate the magnetization inrush current to low value, so this is a excellent method to mitigation of magnetization current in transformer. The next technique to discrimination of fault currents and Magnetization inrush currents in transformer using fuzzy controller method. That Fuzzy Logic Controller technique can successfully discriminate the magnetization inrush currents and fault currents. Moreover, fuzzy controller classify different fault conditions. There are LL fault, LG fault, LLLG fault. Hence the Fuzzy controller gives proper signal to differential relay for tripping the circuit breaker in fault condition only.

VIII.SCOPE FOR FUTURE WORK

By taking simulation results the reduction of residual flux and inrush currents is good for system to avoid tripping problems and developing new methods to reduction of residual flux from this paper. By the Implementation of the model to discriminate the inrush currents and fault currents, by verifying Experimental setup of simulation result of neural network.

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